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ABSTRACT

The Cheche Konnen (Haitian Creole for "search for knowledge") project was designed to address the following concerns in the education of language minority children: limited access to science and mathematics education, separation of science and mathematics from literacy development, isolation in and outside of school, and inadequate teacher preparation in science and mathematics. In Cheche Konnen, students plan and carry out investigations of phenomena in the natural world. The students pose questions, plan and implement research to explore them, build and revise theories, collect, analyze, and interpret data, and draw conclusions and make decisions based on their research. An evaluation of the program's first year focuses on the extent to which students began to acquire scientific ways of talking and reasoning. Data are both quantitative and qualitative, drawn from problem-solving protocols administered individually in interviews at the beginning and end of the 1988-89 school year. Students were in a combined 7th-8th grade self-contained bilingual classroom (n=20) and in a basic skills program within a large high school bilingual program (n=22). Interview excerpts and interpretation are presented. It is concluded that the approach has been successful in teaching scientific thought and discourse through authentic scientific activity. (MSE)

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Appropriating Scientific Discourse: Findings from Language Minority Classrooms

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Appropriating Scientific Discourse: Findings from Language Minority Classrooms

For the past two years, we have been working with teachers in the bilingual program of a large, urban public school system to create and evaluate a model of collaborative inquiry in science for language minority students (Warren, Rosebery & Conant, 1989; Rosebery, Warren & Conant, 1989). The project, known as Cheche Konnen ("search for knowledge" in Haitian Creole), is designed to address several critical concerns in the education of language minority children: (1) limited access to quality science and mathematics education, (2) the separation of science and mathematics learning from literacy development, (3) the isolation of language minority students from mainstream communities both inside and outside the school, and (4) inadequate teacher preparation in the core academic disciplines of science and mathematics.

In this paper we report the results of an evaluation of the first year's field test of students' learning, examining in particular the extent to which students began to acquire scientific ways of talking and reasoning. The data we present are both quantitative and qualitative. The object of our analysis is a set of problem solving protocols administered individually in the form of an interview to the students at the beginning and end of the 1988-89 school year.

The Cheche Konnen Approach

In Cheche Konnen, we have been developing, implementing and evaluating an approach to science in which language minority students plan and carry out investigations into phenomena in the natural world, e.g., water quality, weather and human physiology. The basic idea is to involve the students, most of whom have never studied science before and some of whom have had very little schooling of any kind, in "doing science" in the ways that practicing scientists do. Students pose their own questions, plan and implement research to explore their questions, build and revise theories, collect, analyze and interpret data, and draw conclusions and make decisions

based on their research.

This approach contrasts sharply with traditional classroom practice in science in which lecture, demonstration, memorization and assessment predominate (AAAS, 1989; Mullis & Jenkins, 1988). In traditional school science, students do not typically engage in any direct or purposeful way the phenomena they are expected to understand. They may master some of the so-called "facts" of science but they learn very little about the nature of the scientific enterprise or scientific knowledge.

For language minority students, conventional school science is even more problematic. Science instruction, when it is given at all, typically takes the most limited, traditional forms. Often it is subordinated to the pressing – and legitimate – need to develop the student's English language skills; students memorize the definition of the word "hypothesis" but never experience what it means to formulate or evaluate one. As a result, very little science is actually learned. Perhaps more importantly, this kind of learning may inculcate negative attitudes and conceptions about science, especially in language minority students, many of whom come to school without a strong sense of what science in the world outside of school is all about.

In Cheche Konnen, students actively construct scientific understandings through collaborative, interdisciplinary inquiry. The emphasis in Cheche Konnen on collaborative inquiry reflects our belief, building on Vygotsky (1978), that robust knowledge and understandings are socially constructed through talk, activity and interaction around meaningful problems and tools. We have found that the distribution and sharing of intellectual responsibility is particularly effective for language minority students, for whom the language demands of tasks can be overwhelming and can often mask their abilities and understanding. In addition, collaborative inquiry creates powerful contexts for constructing scientific meanings. In challenging one another's thoughts and beliefs, students must be explicit about their meanings; they must negotiate conflicts in belief or evidence; and they must share and synthesize their knowledge in order to achieve understanding (Barnes & Todd, 1977; Brown & Palincsar, in press; Hatano, 1981; Inagaki & Hatano, 1983; Rosebery, et al., 1990; Tharp & Gallimore, 1988; Warren et al.,

1989).

Cheche Konnen investigations are also interdisciplinary; science, mathematics and language (talk, reading, and writing) are intimately linked. Mathematics and language are recognized as essential tools of scientific inquiry, which stands in contrast to traditional schooling in which science is separated from math and the role of language in each is hardly acknowledged. The importance of an interdisciplinary approach cannot be overstated with regard to language minority students. It involves them directly in the kinds of purposeful, communicative interactions that promote genuine language use, which arguably are the most productive contexts for language acquisition, such as talking in the context of doing science and trying to solve a meaningful problem (Trueba, Guthrie & Au, 1981). It also creates opportunities for students to use the languages of science and mathematics in ways that society requires: not just to read textbooks, but to write reports, argue a theory, develop evidence, and collaboratively solve problems.

A Sociocultural Perspective on Scientific Literacy

The Cheche Konnen model of collaborative inquiry is informed by a particular perspective on what it means to be, or become, scientifically literate. In Cheche Konnen, scientific literacy is conceptualized as a discourse (Bakhtin, 1981; Gee, 1989). This view of science as a discourse helps us to see scientific literacy not as the acquisition of specific facts and procedures or even as the refinement of a mental model, but as a socially and culturally produced way of thinking and knowing, with its own ways of talking, reasoning, and acting, its own norms, beliefs and values, its own institutions, its shared history and even its shared mythologies (Gee, 1989; Latour, 1987; Longino, 1990). With this view of scientific literacy comes the view that to become scientifically literate, students (and teachers, too) need to be *enculturated* into the ways of making sense that are characteristic of scientific communities. They must learn to use language, to think, and to act as members of a scientific community.

This view of scientific literacy is at odds with that which underlies school science practices, whether in mainstream or bilingual programs. Some of the

most forceful testimony on this point comes from practicing scientists. For example, in the following quote Sir Peter Medawar (1987, p.111), the Nobel Laureate, describes a scientist's view of scientific activity:

> Like other exploratory processes, (the scientific method) can be resolved into a dialogue between fact and fancy, the actual and the possible; between what could be true and what is in fact the case. The purpose of scientific enquiry is not to compile an inventory of factual information, nor to build up a totalitarian world picture of Natural Laws in which every event that is not compulsory is forbidden. We should think of it rather as a logically articulated structure of justifiable beliefs about a Possible World - a story which we invent and criticise and modify as we go along, so that it ends by being, as nearly as we can make it, a story about real life.

In this quotation, Medawar directly challenges some of the typical school beliefs about what it means to be scientifically literate. First, he challenges the belief that science, at bottom, is the accumulation of knowledge or facts about the natural world. Secondly, he challenges the belief that scientists work according to a rigorously defined, logical method, known popularly as The Scientific Method. And thirdly, he challenges the belief that scientific discourse is represented uniquely, or even accurately, by forms of writing and talk that are thoroughly objective and impersonal.

Central to Medawar's vision is an idea of scientific activity as involving dialogue and storytelling. Both strike a discordant note with conventional classroom practices in science. For example, with regard to the methods of science, we tend to confuse the final product of scientific activity, the journal paper with its clearly delineated steps and carefully argued logic, with the process that produced it (cf. Gilbert and Mulkay, 1984). One result is that we teach *the* method of science as if there were only one way in which scientists actually go about their work. Another result is a distorted view of the role of both reason and imagination in science (Kuhn, 1977; Medawar, 1987). Medawar's insistence on the dialogic quality of scientific activity, in contrast, places fact and fancy, induction and imagination on more equal footing.

But what is the character of scientific sense-making? Medawar suggests provocatively that scientific sense-making is akin to storytelling. What does he mean by this? Most of our cultural assumptions about the nature of

scientific knowledge and reasoning, at least those that are conveyed through classroom instruction – for example, that scientific knowledge is associated with certainty and is absolute – do not fit with any idea of storytelling. What kind of storytelling, then, does Medawar have in mind?

What Medawar has in mind when he equates scientific inquiry with storytelling is an activity that "begins with an explanatory conjecture which at once becomes the subject of energetic critical analysis" (1987, p. 134-35). It proceeds by hunch and intuition, invention and criticism; it is a process that, in his view, is "outside logic" (Medawar, 1987, p. 129). And, scientific storytelling is exactly this activity of building explanatory structures or theories through hypothesizing and experimentation. Following Medawar, we characterize the discourse of storytelling in science as a discourse of theorizing, one that grows out of a vigorously critical and iterative process involving at minimum conjecture, evidence, experimentation, and explanation.

For students to become literate in the ways of making sense that are characteristically scientific, the contexts ("communities of practice") in which they learn science must reflect and support those sense-making practices (cf. Lave, in preparation; Schoenfeld, in press); that is, students must be enculturated into the ways of making sense that are characteristic of scientific communities. But learning the practices and discourse(s) of science is a difficult and complicated process. Students must not simply acquire scientific ways of doing, reasoning, talking and valuing; they must also find ways of appropriating scientific discourse so that it can serve their own sense-making purposes (Bakhtin, 1981; Cazden, 1989).

The Soviet theorist, Mikhail Bakhtin, helps us see why appropriation is both so important and so difficult:

> (The word in language) becomes "one's own" only when the speaker populates it with his own intention, his own accent, when he appropriates the word, adapting it to his own semantic and expressive intention. Prior to this moment of appropriation, the word...exists in other people's mouths, in other people's contexts, serving other people's intentions....And not all words for just anyone submit equally easily to this appropriation...: many words stubbornly resist others remain alien, sound foreign in the mouth of the one who appropriated

> them and who now speaks them; they cannot be assimilated into his context and fall out of it; it is as if they put themselves in quotation marks against the will of the speaker. Language is not a neutral medium that passes freely and easily into the private property of the speaker's intentions; it is populated – overpopulated – with the intentions of others. Expropriating it, forcing it to submit to one's own intentions and accents, is a difficult and complicated process. (pp. 293-294)

For language minority students, the appropriation process can be even more arduous than for other students; for the distance they must travel between discourse worlds is often far greater than that for mainstream students, owing to both cultural and linguistic discontinuities (Au, 1980; Au & Jordan, 1981; Heath, 1983; Mohatt & Erickson, 1980; Philips, 1972, 1983). What makes appropriation so difficult is that discourses are inherently ideological; they crucially involve a set of values and viewpoints in terms of which one speaks, thinks and acts (Bakhtin, 1981; Gee, 1989). As a result, discourses are always in conflict with one another – some more or less so – in their underlying assumptions and values, their ways of making sense, their viewpoints, even the objects and concepts with which they are concerned. Appropriating a particular discourse, then, can be more difficult or less difficult depending on the various other discourses in which the students (not to mention the teachers) participate.

In earlier papers we analyzed how students begin to appropriate scientific ways of doing, talking and reasoning in the context of doing scientific investigations (Rosebery et al., 1990; Warren et al., 1989), examining how particular classroom processes foster authentic scientific activity and discourse. In those papers we saw that students' understanding and use of the conceptual tools of science to pose questions, develop hypotheses, formulate theories, and design studies evolved through direct engagement in authentic scientific inquiry. Through their scientific activity, the students directly met a wide range of intellectually demanding challenges such as determining the reliability of their results and constructing explanations to resolve discrepancies between theory and data.

In this paper we are interested in evaluating the effects of the Cheche Konnen approach on students' learning in a problem solving context. The

specific question we address is this: To what extent did the students begin to take control of the discourse of science to build their own understandings of the world? To explore this question, we analyze the students' protocols for changes in what they know and in how they use their knowledge to reason in terms of hypotheses and experiments.

Method

Subjects

The Cheche Konnen model was pilot-tested in two distinctly different contexts of bilingual education within an urban public school system. One was a self-contained, combined classroom of seventh and eighth graders in a K-8 school. The other was a basic skills program within the general bilingual program in a large high school. These settings represent in microcosm many of the variations that can occur in the ages, skill levels, interests, and cultural and linguistic backgrounds of language minority students in an urban school system.

The city is a multiethnic community that has offered bilingual education since 1970. Currently, the city's public schools serve approximately 8,000 students, 1000 of whom receive bilingual education. A somewhat higher percentage of the students in the system do not speak English at home. The city's bilingual population is diverse. To address this diversity, the school system offers bilingual education in eight languages at the elementary-middle school level (Portuguese, Spanish, Haitian Creole, Chinese, Korean, Hindi, Gujarati, and Vietnamese) and in four languages at the high school (Portuguese, Spanish, Chinese and French/Haitian Creole).

Seventh-eighth grade classroom. At the K-8 school, which houses the city's Haitian Creole bilingual program and a mainstream program, we worked with a combined seventh-eighth grade class. The school has 390 students in kindergarten through the eighth grades, one-third of whom are in the bilingual program. It functions as an "alternative" school, offering in its mainstream program a more open-ended and inquiry-based educational program than that found in most schools.

In September, the combined seventh-eighth grade had seven students; by January, the number had grown to 20. The students in this class take their core academic subjects (e.g., language arts, mathematics, social studies) in Haitian Creole from their classroom teacher, and instruction in English as a Second Language from an ESL teacher. Academically, the students range from a few who function approximately two years below grade level to those who cannot read or write in either Creole or English. During the year, science was taught three times a week for 45 minutes each in Creole.

The classroom teacher is a native speaker of Creole and is fluent in English. She has taught in the bilingual program for several years. Prior to the 1988-1989 school year, she had only occasionally taught science.

High School Basic Skills Program. The second classroom was in a large urban high school. The school serves 2700 students and is comprised of several "houses." The bilingual program occupies its own house and serves approximately 250 students, or about 10% of the student body. While the number of language minority students at the high school has remained relatively stable over the last ten years, the ethnic background of the students has changed as immigration patterns have changed. In 1977, three-fourths of the language minority students were Portuguese and Hispanic, and one-quarter were Haitian, Greek and Iranian. Today, 42% are Haitian, 24% are Hispanic, and 10% are Portuguese, and the remaining 24% are Chinese, Vietnamese, Korean, Indian, and Eritrean.

The high school offers bilingual education that in many cases mirrors what is available in the regular monolingual program (e.g., general science, biology, earth science, basic math, pre-algebra, algebra, and geometry). These classes are offered in French/Haitian Creole, Portuguese, Spanish and Chinese. In addition, the bilingual program offers a Basic Skills program for those students whose low academic and literacy skills prevent them from participating in the regular bilingual program. This is the program in which Cheche Konnen was pilot-tested.

The Basic Skills program is for the academically weakest students, those

who are at greatest risk for dropping out or school failure. Some of the students in the program are not able to read or write in their native languages, and most have only the most rudimentary mathematics skills and no previous exposure to science. There were 22 students in the Basic Skills program in the 1988-1989 school year from a variety of linguistic and cultural backgrounds. Six language groups were represented: Haitian Creole, Spanish, Portuguese, Amharic, Tigrinye, and Cape Verde Creole.

Four teachers worked together in the Basic Skills program: two math teachers, an ESL teacher, and a social studies teacher. We worked directly with the math teachers who co-taught science and mathematics four times a week during back-to-back periods of 45 minutes each.

One of the teachers is a native speaker of Haitian Creole, is fluent in English, has a working knowledge of Spanish, and has taught science on occasion in the regular bilingual program but has no special training in it. The other teacher is a native speaker of English, has a good working knowledge of Creole and Spanish, and had never taught science before.

In this report, we limit our examination to those students who (a) are native speakers of Haitian Creole[1] and (b) entered class prior to November 1, 1988 and completed the school year. Sixteen students met these criteria, twelve from the 7th-8th grade and four from the high school Basic Skills class.

Procedure

Students in both classes planned and carried out investigations into local aquatic ecosystems throughout the school year. As background to their investigations, they studied aspects of the chemistry, biology and ecology of local water sources. For example, they directly studied and evaluated such determinants of water quality as pH (what acids and bases are, how they affect the health of water, how to test pH, the causes and effects of acid rain), salinity, and bacteria (what they are, what they look like, how to test for them,

[1] Hispanic and Portuguese students were not included in these analyses because of flaws in the end of the year interview process.

associated diseases/health problems); they analyzed micro- and macroscopic aquatic life; they studied water treatment both directly and through demonstration (floccing, chlorination, desalinization), and so forth. The students in the combined 7-8th grade class applied this knowledge by designing and conducting an investigation into the quality of their school's water. In the high school basic studies class, the students designed and carried out an ecological study of a local pond (see Warren, et al., 1989 for a full description and analysis of these investigations).

Assessment Instruments

To assess changes in students' scientific literacy, the students were interviewed individually in the Fall and late Spring of the 1988-89 academic year. The interviews were conducted in Haitian Creole by a fluent speaker. Pre and post versions of the interview were identical. The relevant portions of the interview for this analysis include two problem solving think alouds.

Problem solving task. For the problem solving task, the students were asked to think aloud about how they would investigate and try to explain two ill-defined but realistic problems. One problem focused on pollution in the Boston Harbor (the "Boston Harbor" problem) and the other on a sudden illness in a school (the "Sick Kids" problem). The Boston Harbor problem was based on a Boston Globe newspaper report; the Sick Kids problem on an article entitled "Mass hysteria among schoolchildren: Early loss as a predisposing factor," Archives of General Psychiatry (vol. 39, 1982, pp. 721-724).

The problems were chosen to represent different degrees of transfer. The Boston Harbor problem represents near transfer; it asks students to reason through a problem involving water contamination, a subject they studied during the school year. It is therefore a problem to which they can apply directly knowledge and skills they learned in the context of the water quality investigation. The Sick Kids problem represents far transfer; the students did not study anything directly relevant to it during the school year. The question of interest in this case is how they reason through a problem on a subject they have not explicitly studied, that is, whether they have assumed

enough control over scientific discourse to apply it in unfamiliar domains.

The procedure was as follows. The interviewer explained to the student that she was going to read her/him a story about the Boston Harbor or what happened to some kids one day in school. She then posed some questions. A small set of core questions were developed, but the interviewer was instructed to go beyond them to probe the students' meaning and answers. The text of the two problems and the core set of questions are shown in Table 1.

Insert Table 1 about here

The protocols were translated from Creole to English for analysis purposes. The students' responses to the Boston Harbor problem were coded for (a) specific content knowledge developed in the context of the water quality investigation, (b) the number of hypotheses, and (c) the number of experiments. Their responses to the Sick Kids problem were coded for the number of hypotheses and experiments only; knowledge was not considered in this problem since the students did not study this or related topics directly during the year). The number of hypotheses, experiments, and appropriate uses of content knowledge were counted for the pre- and post-interviews, respectively. The interviews were coded independently by two raters who, before undertaking the main coding task, reached a high degree (95%) of agreement on two transcripts not included in the analyses. After coding, the raters met to review their results. Any disagreements were resolved through discussion.

Content knowledge encompassed the appropriate use of concepts related to water quality or scientific procedures, including reference to possible causes of water pollution, explanation of their effects, methods for detecting the presence of pollutants, and the procedures for applying these methods. As an example, we include the following excerpt from a seventh grader's post-interview in which we coded three instances of appropriate content knowledge use: (1) acid as a possible pollutant; (2) a description of how litmus paper works; and (3) an explanation that too much acid can cause fish to die.

Example 1: (Post/Boston Harbor)
I: ...are there other things you'd check?
Eclide: I could test to see if it were acid that were doing that to the water.
I: How do you find out if there's acid in water?
Eclide: There's a kind of little paper you brought to show us, you can leave it in [the water]. It's the color; if it's acid, you'll know according to the wayit's colored. You look to see which is the most acid and which is less acid. If there is too much acid in the water killing the fish, you can look at that to see.

Hypotheses were defined as explanatory conjectures, statements that suggest a cause for the situation described in the problem. Furthermore, to be counted, they must be testable in principle, although the student may not actually propose a test. Hypotheses that reiterated examples (or "symptoms") stated in the problem story were not counted. Each hypothesis was counted only once, regardless of the number of times it was articulated or rephrased. For instance, in Example 1 above, acid was counted as one hypothesis because it was offered as a possible cause of dead fish and because it is testable. In Example 2 below, spoiled food and garbage were not counted because they are mentioned in the problem and "things they left in it" was not counted because it is not testable.

Example 2: (Pre/Boston Harbor)
I: What do you think could make the water like that?
Jonese: The things they left in it, like the spoiled food, and things, the nasty fish that died, and car gas.
I: Car gas - ?
Jonese: And the garbage they left in.

In looking at *experiments*, we considered several facets of experimentation relevant to the students' experience during the water quality investigation. Much of the students' experience with experimentation consisted of testing water for the presence of a given pollutant using chemically-based methods (e.g., litmus paper, growing bacterial cultures). They did not have much experience with classical experimentation (e.g., controls and treatments). For the purpose of this analysis, therefore, we did not define experiments in the classical sense. Rather, we looked for the following kinds of evidence in identifying experiments in the students' protocols: first, that they know when and how to apply a given test in

relation to a specific hypothesis; secondly, that they have the idea that it is necessary to isolate a variable, even if they do not know how to do so in a controlled way; thirdly, that they have some notion of treatment (that is, of doing something to someone or something that will produce the expected effect). Clearly, if students defined more rigorous experiments, we counted them as well.

Example 3 contains two experiments, one testing the effect of garbage on fish and the other testing for the presence of fecal coliform bacteria. (Kenia's description of the second experiment is a heavily context-dependent reference to fecal coliform bacteria tests performed in class using Millipore Samplers.) In contrast, in Example 4, Andrew does not put forward any experiments. His response to the interviewer's question is an assertion of fact rather than a procedure for testing an idea.

Example 3: (Post/Boston Harbor)
I: What might make the fish die?
Kenia: They're allergic to the dirty garbage.
I: Ok, how would you make sure that what you think is true?
Kenia: I would take a little garbage in the water, I would take a fish, and give it to it to eat to see if it would die.
I: What if it doesn't die?
Kenia: If it doesn't die, it's another reason.
I: Can you think of another reason the fish might die?
Kenia: If the water had too much fecal in it?
I: How would you know if it had fecal in it?
Kenia: I'd take the water and put it in the same thing we had to see if the water had fecal in it (referring to a Millipore Sampler). I would put it in, I would do the same thing as we did, after that I would look at it.

Example 4: (Pre/Boston Harbor)
I: How would you know that it was the garbage that was making the foam and the fish die?
Andrew: The garbage made the fish die.
I: How would you make sure?
Andrew: Because fish don't eat garbage, they eat plants under the water.

Results

In this section we report the quantitative results for the two problems. In the discussion that follows, we consider the results from a broader, more

qualitative perspective, examining in more detail some of the changes in students' discourse from the beginning of the year to the end.

The first result to report is a general one, having to do with the length of the interviews. The post-interviews lasted nearly twice as long on average as the pre-interviews: 40-45 minutes versus 20-25 minutes. This indicates that the students generally had more to say in the post-interview than in the pre-interview. The next set of results focuses on changes in what the students knew and how they used their knowledge to reason scientifically in terms of hypotheses and experiments.

Content Knowledge

For the Boston Harbor problem only, paired t-tests were performed on pre- and post-interview uses of content knowledge in the domain of water quality, as defined in the previous section. There was a significant increase in the number of appropriate uses of content knowledge in the post-interviews (Figure 1). The mean number of appropriate uses of content knowledge increased from 0.50 in the pretest to 5.75 in the posttest ($t=8.72$, 15 df, $p<0.000$).

Insert Figure 1 about here

Hypotheses

Paired t-tests were performed on the number of hypotheses the students generated in the pre- and post interviews. In both the Boston Harbor and Sick Kids problems, the mean number of hypotheses put forward increased significantly from the pre- to the post-interviews. The results for each problem are shown in Figure 2. For the Boston Harbor problem the mean number of hypotheses increased from 1.7 in the pre-interview to 4.2 in the post-interview ($t=8.26$, 15 df; $p<.0.000$). Similarly, for the Sick Kids problem, the mean number of hypotheses was 1.9 in the pre-interview and 3.8 in the post-interview ($t=7.3$, 15 df; $p<.0.000$).

Insert Figure 2 about here

Experiments

For each problem, we also found a significant increase in the mean number of experiments (see Figure 3) as defined in the previous section. For the Boston Harbor problem, the mean number of experiments was .88 on the pre-interview and 3 on the post-interview ($t=7.1$, 15 df, $p<0.000$). For the Sick Kids problem, the results were similar: a mean of .88 experiments on the pre-interview as compared with 3.6 on the post-interview ($t=11.0$, 15 df, $p<0.000$).

Insert Figure 3 about here

All in all, the results suggest that the students knew more in the post-interviews than in the pre-interviews and that they were better able to organize their reasoning around hypotheses and experiments. A closer look at the students' protocols will help us understand more deeply the nature of those changes and, in particular, whether the students were beginning to acquire some degree of control over scientific discourse as a way of thinking and talking.

Discussion

The foregoing results suggest that the students' reasoning has begun to change. But it is not easy to tell from such results in what ways specifically it has changed or why. From a discourse perspective, we want to know if, in general, the students' ways of talking science are different in the post-interviews than in the pre-interviews and, if so, why they are different. Specifically, what kinds of discourse strategies do they use to organize what they know into hypotheses, experiments and explanations?

Pre-Interviews

As the numerical results from the pre-interviews attest, in September the students did not reason scientifically: they offered few hypotheses and even

fewer experiments. But what do we mean when we say their reasoning is unscientific, that they do not talk scientifically? How did they reason about the problems? To address this question, we examine the discourse strategies they used to answer the interviewer's questions, particularly those which were intended to elicit hypotheses and experiments.

Asked in the pre-interviews, "What could be making the water like that (i.e., full of garbage, foam, dead fish)?" or "What could be making the children sick?", the students, with few exceptions, tended to respond with short, unelaborated, often untestable "hypotheses" which simply restated the phenomena included in the problem description.

Example 5: (Pre/Boston Harbor)
I: What do you think might make the water like that?
Kerline: Some people who dropped garbage in the water.
(...)
I: Why, what might make the water full of foam?
K: The stuff they dropped in.

Example 6: (Pre/Boston Harbor)
I: What's the first thing you do?
Emmanuel: What happened in the water, they put a poison in the water. A person put something in the fish so they die. All the fish died because the water was spoiled. That's why it's dirty.
I: What kind of poison?
Emmanuel: A water poison, to make the water dirty.
I: Why would they do that?
Emmanuel: If someone wanted to kill someone else, to kill the person, he puts it in the water.

Example 7: (Pre/Boston Harbor)
I: What might be in the water that would make it like that?
Joanne: Something they left in it that the fish don't like, something they can't live with and they die.

Example 8: (Pre/Sick Kids)
I: Why do you think they all got sick at the same time?
Kerline: That's a thing.
I: What kind of thing?
Kerline: Ah, I could say a person, some person that gave them something.
I: I don't understand.
Kerline: Anything, like give poison to make his stomach hurt.

These four examples are typical of the students' responses. They invoke an anonymous agent, "people," as the cause of the pollution or the sudden illness among the schoolchildren. Most of the "hypotheses" they put forward are of the "black box" variety: "stuff" they put in, "something" they left in, a "thing," even a "poison" which, although semantically richer by definition, is functionally equivalent to the other terms (i.e., poison makes the fish die). Not one of these notions has any explanatory power. None therefore qualifies as an hypothesis by our definition.

These examples suggest that the students are relying on two discourse strategies to address the interviewer's why-questions. One is to invoke anonymous others ("they," "someone," "people") as the cause of the problem. Another is to treat the symptoms as the cause, literally to extract items from the problem story itself and assert them as the cause of the harbor's problem ("garbage," "dirt," "dead fish"). And, having identified a particular agency, however vaguely defined, the students do not then pursue any further analysis. It is as if they are saying: "You asked me a question and I have given you the answer. What more is there to say?" In virtually every case in the pre-interviews, the students stayed at the surface of the problem, treating it as if it were a text that had all the answers. In keeping with this view, they saw their job as being not to reason through the problem but simply to locate and identify the answers in the text. Thus, in the pre-interviews, it seems clear that the students do not have a strong sense of what counts as a reasonable hypothesis or explanation. Put more strongly, at the beginning of the year, the students do not have any sense at all of what a hypothesis is functionally, let alone formally, in science.

The students' "text comprehension" strategy is not surprising if we consider the kinds of worksheet- and textbook-based practices that they are accustomed to the typical American classroom. If anything, the students' school experiences in Haiti were even more restrictive, where rote recitation and memorization are the rule. This reluctance to go beyond what is given in the problem may also have roots in the early language socialization experiences of Haitian children, in which it has been observed in some situations that meanings are neither actively negotiated nor analyzed between caregivers and children (B. Schieffelin, personal communication,

May 1990). None of these experiences prepare the students for active, critical inquiry of the kind found in scientific discourse.

Another strategy was also in evidence in the pre-interviews. Students frequently invoked personal experiences as the source of and as evidence for their hypotheses. These might be first-hand experiences or second-hand stories. One student, for example, evaluated the Sick Kids problem according to her personal beliefs about and experience with Satanic illnesses:

> **Example 9:** (Pre/Sick Kids)
> I: ...Why do you say it's a Satanic illness?
> Eclide: The reason why I say it is is they all (the kids) got sick at the same time. If it weren't Satan, they wouldn't all get sick at the same stroke....But why I'm not finished answering this more clearly for you is because my grandmother was sick with a Satanic illness, we went to the doctor and he didn't see that she had anything, but she still suffered a lot inside and she got one shot in the hospital and then she died...

This example differs from the earlier ones in that Eclide shows evidence that she is approaching the problem somewhat scientifically, without actually constructing a scientifically acceptable explanation. Specifically, she takes a fact asserted in the problem story, that the kids all got sick at the same time, and uses it as a constraint on her own reasoning about the cause of the illness. She then makes sense of her analysis of the case in terms of a model of Satanic illness drawn from personal experience. However, it is an experience very much at odds with what counts as valid scientific knowledge. Eclide therefore ends up sounding unscientific, even though her analysis was up to a certain point distinctly scientific: she transformed data (e.g., that all the kids got sick at the same time) into a constraint which she then used to evaluate a particular causal model (the model of Satanic illness), albeit one that doesn't qualify as scientific.

Students also used the discourse strategy of invoking personal experience to organize their answers to questions calling for experiments. In these cases, they invoked personal experiences as *evidence* to justify a particular hypothesis (cf. Michaels and Bruce, 1989). A few examples of this kind of reasoning follow:

Example 10: (Pre/Boston Harbor)
I: How would you find out what kind of poison it was?
Eclide: I don't know what kind of poison it is, but what makes me say it is that in Haiti they used to drop something in the water and the fish would die and they said it was poison, too.

Example 11: (Pre/Boston Harbor)
I: How would you find out if you were right?
Leducto: And people might have thrown in things to kill them, too.
I: Like what?
Leducto: In Surinam there's a thing the people do, they leave something in the water. You need fish to eat now, they leave it in the water and, you see people don't know, but it is they who did it. The next day you see a lot of fish and they go sell them.
I: Mm. How would you know it were because of that that the fish died? You see the fish are dying, you think it might be that, how would you check?
Leducto: Because the water got black...

Example 12: (Pre/Sick Kids)
I: ...How would you know if it's that (the food)?
Marie France: I don't know. Sometimes when I ate here at school, they gave me food I didn't like, and it didn't...suit my body, and I got sick.

These examples, which are representative of the pre-interview protocols, suggest that at the start of the year the students do not have *any* sense of experimentation as a critical, hypothesis-testing process. In fact, they do not take up the interviewer's bid at all (see immediately following paragraphs for more on this point). Rather, the students seem to be conceptualizing evidence *not* as data produced through experimentation but as information already known, either through personal experience or second-hand sources. It is not, in these examples, even common knowledge; it is personal knowledge, plain and simple.

The recourse to personal experience is actually only one instance of a more general strategy for dealing with "How would you be sure?" questions in the pre-interviews. This question actually took several forms, among them: How would you make sure (you were right)? How could you check to see if your idea was right? How would you know it's because...? How could you know it's true? The intent of these questions was to elicit experiments or other analytic methods (e.g., microscopic analysis, observation) that could help in evaluating a given hypothesis. It also led, as we have just seen, into

questions of evidence: What would it take to confirm or disconfirm a given hypothesis?

The students' responses to the experiment-elicitation questions in the pre-interviews suggest that they did not interpret them in the way they were intended, as calling for experiments. Rather, they interpreted them as calling for an explanation or an assertion of their knowledge: "How do you know?", "Why do you say that?" or "What did the story I just told you say about this?" Some examples follow:

Example 13: (Pre/Boston Harbor)
I: What do you think might have made the fish die?
Andrew: Because the garbage is a poison for them.
(...)
I: How would you know it were the garbage that were making the foam and the fish die?
Andrew: The garbage made the fish die.
I: How would you make sure?
Andrew: Because fish don't eat garbage. They eat plants under the water.

Example 14: (Pre/Boston Harbor)
I: Why don't they (the fish) find things to eat if there's garbage in the water?
Kerline: Because the garbage isn't good. The food they would need gets spoiled.
(...)
I: OK, ... how would you be sure it were because of the garbage that the fish died?
Kerline: Because the garbage isn't good.

Example 15: (Pre/Boston Harbor)
Frantzy: It's because the water is dirty that the animals are dying. If the water weren't dirty, the animals wouldn't be dying.
(...)
I: How would you be sure, make sure that it's that that made the fish die?
Frantzy: It's because of that, because the water is too dirty.

Example 16: (Pre/Sick Kids)
I: OK. You said something they ate made them sick. How would you be sure it were because of that that they got sick? How would you ckeck? How would you know?
Leducto: Because he ate something bad at home. Then, he might have had an illness and the doctor had given him a pill but he didn't take it. That might have caused it. Then he might have taken too many pills which made his head swim. Then he might have had a seizure.

Example 17: (Pre/Sick Kids)
I: Can you explain why the students got the illness they have, why they got stomachaches at the same time?

Kenia: Because they ate the same thing.
I: How would you find out if they all ate the same thing? How would you make sure?
Kenia: Because they all have the same illness.

As these examples make clear, the interpretation of the experiment-elicitation question as a call for an explanation or an assertion of knowledge was a favored one among the students in the pre-interviews. That they are interpreting it in this way is most clearly revealed by the way each one explicitly marks his or her answer as an explanation. Note how in each example the students use "Because..." to initiate virtually every utterance. We see this over and over again in the pre-interview protocols. Moreover, the "explanations," as we have seen before, are drawn from the text of the problem story, from prior knowledge, and from narrative invention. Like the students' earlier hypotheses, they have no explanatory power.

A similar interpretation was in evidence in the context of another question with which the interviews typically opened: "What is the first thing you would do?" Several students interpreted this question to mean, "What do you think happened?", rather than "What would you, as the scientist, do first?":

Example 18: (Pre/Boston Harbor)
I: What's the first thing you do?
Emmanuel: What happened in the water, they put a poison in the water, a person put something in the fish so they die. All the fish died because the water was spoiled. That's why it's dirty.

Example 19: (Pre/Boston Harbor)
I: What's the first thing you do...to find out what's wrong with the water?
Jonese: Because...
I: What do you do?
Jonese: They dropped nasty things in the water, like garbage...that's why the fish can't live, because they die... The water gets dirty and then the fish can't live, they die.

On first glance, putting forward an "explanation" is not necessarily an unproductive response to the opening question, if it is intended as an hypothesis that initiates further inquiry. But the language of the students' responses does not invite the inference that they are proposing an hypothesis which they will then evaluate. Rather, as we have seen in earlier examples,

their discourse is the discourse of school. They are literally trying to explain what happened, as if they are answering a reading comprehension question. Questions of the "What happened?" variety, it hardly needs to be noted, are among the most prevalent kinds of questions in most school literacy tasks (Durkin, 1978-79).

To summarize, then, in the pre-interviews students did not show any evidence that they understand what it means to reason scientifically and, specifically, to put forward hypotheses having deductive consequences that can be evaluated through experimentation. Instead, it is as if they have determined that the discourse context in which they find themselves is no different from that of most school tasks, in which literal comprehension is valued over inferential reasoning and in which questions are asked by a knowing adult to ascertain whether the student has got the right answer or not. As we have seen repeatedly, the students do not adopt the perspective suggested to them by the interviewer in her introduction to the problem: "You are a famous scientist....What is the first thing you would do to find out what was wrong with the water?" Nor do they show any tendency to analyze the information given, to go beyond it, unless it is to use personal experience as evidence for a particular belief. Rather, they limit the range of their thinking to what is contained within the problem as given.

In contrast to everyday school discourse, the discourse of conjecture and experimentation calls for critical, analytic evaluation of given information or evidence: What are the symptoms? What could possibly explain them? How can I evaluate my ideas? It remains to be seen to what extent in the post-interviews the students began to take control of scientific discourse.

Post-Interviews

The earlier quantitative results clearly suggest that the post-interviews differ significantly from the pre-interviews. In this section we will examine, again through examples of students' talk, changes in knowledge and how students use their knowledge to organize their reasoning in terms of hypotheses, experiments and explanations.

The first example illustrates the effects of knowledge on students' reasoning, that is, of students knowing more about water pollution in the post-interviews than they did in the pre-interviews. In this example, Martine explains how she would clean the water, describing in fairly precise chemical detail how she would rid the water of bacteria and other matter:

Example 20: (Post/Boston Harbor)
I: What would you do first?
Martine: I'd clean the water.
I: How?
Martine: Like you'd take the garbage out of the water, you'd put a screen to block all the paper and stuff, then you'd clean the water, you'd put chemical products in it to clean the water, and you'd take all the microscopic life out.
I: What chemical products would you put in?
Martine: Chlorine and alum, you'd put in the water.
I: What would that do?
Martine: They'd gather the little stuff, the little stuff would stick to the chemical products, and they would clean the water.

In the example, Martine paints a chemically accurate account of how alum works in the process of flocculation: it "gather(s) the little stuff, the little stuff would stick to the chemical products...". How did she learn this? From a field trip to the local water treatment plant in February, which was conducted in English by one of the plant's chemists. It is striking that in June – five months later – she is using that knowledge productively and spontaneously. Also note that Martine wasn't asked in the interview how she would clean the water; she was simply asked what she would do first. It is clear from this example, which is one of many, that students knew more about water quality and treatment in June than in September.

More interesting, however, is the way in which students *used* their newly acquired knowledge to generate hypotheses. Recall how in the pre-interviews the students' hypotheses often repeated facts reported in the problem story itself. The rare original hypothesis was unelaborated and, more often than not, untestable. In the post-interviews, a different explanatory strategy emerges. Not only do the students put forward more testable hypotheses, but they begin to link them to the larger eco- or aquatic system. For example, the pre-interview "hypothesis" that garbage caused the fish to die is elaborated in

the post-interviews of several students in terms of the effects of waste disposal systems on local water sources:

Example 21: (Post/Boston Harbor)
I: What do you think could make the water like that?
Kerline: Like the things people flush, and like when you finish in the kitchen, the dirty water, garbage would enter into the water. The water would be contaminated and now it wouldn't be any good for people to use.
I: What do you think could make the fish die?
Kerline: Like what comes out of the bathrooms and what comes from the kitchen mixed together. They'll mix together. Because there are certain things you use in the kitchen that fish don't eat.
(...)
I: But, like, I don't understand exactly how the garbage kills them.
Kerline: The garbage could have other things in it, too. Chemical products could kill them too, maybe.

In this representative post-interview example, Kerline – who talked about "things" in the pre-interview – identifies waste disposal systems as a possible source of contamination by linking everyday household activities such as flushing to the Harbor's pollution. What is significant here is the way in which she uses a larger explanatory framework *generatively* to formulate her hypothesis and then to specify it in terms of chemical products as a possible cause of the Harbor's pollution. Kerline's response suggests that she is beginning to understand that hypotheses do not come out of nowhere; they are not the product of naive observation; nor are they simply guesses. Rather, they are informed conjectures that have the power to explain observed effects. Note, too, how in her answer Kerline no longer ascribes the problems in the Harbor to anonymous agents as in the pre-interviews. In the post-interview, ordinary people are responsible, or the systems that serve them are, not bad people or other unusual agents intent upon doing bad things to others.

The larger system framework was also invoked for other hypotheses. For example, some students speculated that high acidity levels might be killing the fish. When asked how acid can kill fish, Eclide explained:

Example 22: (Post/Boston Harbor)
Eclide: The acid can kill if it's too strong. Like if it's used to living in a water that doesn't have...that has a little bit of acid and you leave something in it that is more acid, it can die.

This awareness of system was also in evidence in other parts of the post-interview protocols. Later in her interview, for example, Eclide explains how water could be cleaned using a machine that filters it. The interviewer asks her what she would do with all the bad stuff the machine extracted from the water:

> **Example 23:** (Post/Boston Harbor)
> I: **And what would you do with the bad stuff?**
> Eclide: **When you finish you'd take** it out, out of the machine.
> I: **And where would you put it?**
> Eclide: **You can't leave it on the ground.** If you leave it on the ground, the water that, the earth has water underground, it will still spoil the water underground. Or when it rains it will just take it and, when it rains, the water runs, it will take it and leave it in the river, in where the water goes in. Those things, poison things, you aren't supposed to leave it on the ground.

Eclide's answer reveals that she has begun to develop a model of an integrated water system in which an action or event in one part of the system (e.g., "when it rains") has consequences for other parts of the system (e.g., the water "will take it (the bad stuff) and leave it in the river...").

These examples of change from the pre- to post-interviews are at least in part attributable to changes in the students' knowledge base: they know more about water and aquatic systems than they did at the beginning of the year. But knowledge alone cannot explain the fact that the students put forward more hypotheses and experiments in the Sick Kids post-interviews – a topic they did not study during the year. Rather, the results suggest that the students are doing more than acquiring factual knowledge; they suggest that students are beginning to be enculturated into a new discourse community in which conjecture and experimentation are characteristic modes of inquiry. What is the evidence for this claim?

In both problems in the post-interviews, the students tend to put forward a chain of hypotheses of the "if not this, then this" or the "I'd check this and this" variety. In the Sick Kids problems, they enumerate such possible causes as illness, air, water and food, as in the following examples:

Example 24: (Post/Sick Kids)
I: What do you think might be making the children sick?
Eclide: (Laughs) I'd think it would be an illness someone had and he infected the ones sitting next to him, like one sat next to the other and got it and the next got it until everybody got it.... If it's not that, it could be something they ate. They all might have eaten the same thing and it didn't agree with them.

Example 25: (Post/Sick Kids)
I: What would you do to know what were making them sick?
Martine: I'd test to see what the kids had eaten and I'd test the water, too, what might have passed in the water that wasn't good, that had microbes, that might have animals (microscopic animals) in it to make them sick.

As you can see, the character of the students' hypotheses about the cause of the Sick Kids phenomena has changed. As in the Boston Harbor problem, in the post-interviews they are putting forward testable hypotheses (e.g., illness, food, water), and they are not invoking outside agents to explain the problem. Moreover, the conditional language (the "ifs," "woulds," and "coulds") they use contrasts sharply with the at once assertive yet vague language they used in the pre-interviews (e.g., "What happened was...", "Someone dropped something in...", "Because..."). What this suggests to us is that the students are becoming aware of the probationary status of hypotheses as a methodological tool in scientific inquiry.

In summary, then, in the post-interviews, the students go beyond the information given to put forward hypotheses that are at once explanatory and testable. They are no longer bound to the problem statement as in the pre-interviews for their "answers." Hypotheses now serve to give direction to their inquiry, to link stated symptoms to possible causes and to confine the domain of observation to something smaller and more precise than the phenomena noted in the problem. Moreover, there is the sense from the students' language – in the way they put forward more than one hypothesis and in their use of conditionals – that they are becoming aware of the tentative character and methodological function of hypotheses; hypotheses do not guarantee answers but they do help delimit the scope of one's inquiry. Indeed, as we shall see shortly, the students' post-interview protocols suggest that hypotheses now function as part of a larger inquiry process linking conjecture and experimentation. In the rest of this paper we focus on the

ways in which in the post-interviews the students interpreted and responded to the "How would you be sure..."-type questions (i.e., those that were intended to elicit experiments and evidence).

Recall how in the pre-interviews the students interpreted the "How would you make sure/How would you check...?" and also the "What's the first thing you'd do?" questions as if they were calling for an explanation based on the facts of the story as given or for an assertion of personal knowledge. They did not interpret those questions as calling for experiments or other forms of analysis. In the post-interviews, they respond to these questions in a distinctly different way, suggesting various analytic procedures and, in several cases, explicitly linking them to a specific hypothesis (e.g., bacteria, water flow):

Example 26: (Post/Boston Harbor)
I: What would you do first?
Kerline: You'd take the water to do an experiment with it...The water, I'd try to find out what was in it.

Example 27: (Post/Boston Harbor)
I: How would you find out if what you think is true?
Kenia: ...I would follow, I would look to see what kind of thing were next to the water, if there was water that was coming from other places into the water.

Example 28: (Post/Boston Harbor)
I: What's the first thing you would do?
Leducto: What would I do? I'd take the water and I would see what it has in it that, if has, I'd see if it has bacteria in it.

In these examples, the students are now treating the facts recounted in the problem as evidence in need of an explanation rather than as the explanation itself. Two of the students propose to analyze the water; the other proposes to begin her analysis by monitoring the flow of water into the Harbor. In every case, the actions they suggest are exploratory but directed, two qualities that are clearly marked in their discourse through verb tense and selection: "I'd try to find out what was in it." "I would look to see...if there was water that was coming from other places into the water." "I would see what it has in it...I'd see if it has bacteria in it." Given what they know about water systems in general and about polluted water systems in particular, they have

an idea – an "imaginative preconception" in Medawar's (1987, p. 122) phrase – of what they might reasonably expect to find.

Similarly, in their post-interview responses to the question, "How would you check...?", the students begin to reason in terms of experiments, in the simple sense we defined earlier. Most involved testing one variable without controlling for other variables, although several did build in explicit comparisons. In the following representative example, one student, having hypothesized a cause (e.g., garbage) for a reported effect (e.g., dead fish), then describes her experiment, the goal of which is to reproduce the effect (e.g., the fish die):

Example 29: (Post/Boston Harbor)
I: Okay, but how would you make sure what you think is true?
Kenia: I would take a little garbage in the water, I would take a fish and give it to it to eat to see if it would die.
I: What it if doesn't die?
Kenia: If it doesn't die, it's another reason.

What is significant about Kenia's reasoning is the step forward it represents from the pre-interviews where the students had no sense of the critical connection between conjecture and experimentation. To be sure, she still has some distance to go to refine her experimental logic. In its current form, it is as if the goal of her experimentation is to produce the expected effect, not to understand its cause. Nevertheless, what is clear is that, whereas in the pre-interviews, the students viewed their problem-based or personal knowledge-based explanations as sufficient evidence to explain phenomena, in the post-interviews they seem to be developing some sense, if still incomplete, of the way in which conjecture and experimentation function in scientific inquiry. This is perhaps most evident in the last line of the example when Kenia acknowledges that falsification is one possible outcome of experimentation, one that then requires the investigator to develop a new hypothesis ("reason" is her term). Here Kenia's reasoning suggests that she is very much aware that hypotheses drive scientific inquiry and that experimentation is the means for developing evidence. Evidence is no longer conceptualized simply as information already known or given as in the pre-interviews but as the product of experimentation undertaken to determine the truth of a specific hypothesis.

Not all the one-variable instances were of this simple type, however. In a few cases, the students embedded the testing of variables in an iterative process, in which one variable after another is tested until the reported effect is produced. In some other cases, the students went beyond this simple model and built contrasts into their experimental design, as in the following example:

Example 30: (Post/Boston Harbor)
Kerline: I'd put a fish in clean water and one fish in a water full of garbage. I'd give the clean water fish food to eat and the other one in the nasty water, I'd give it food to eat to see if the clean water, if the one in the clean water would die with the food I gave it, if the one in the dirty water would die with the food I gave it.
I: Would you give them the same food? What would you give the second one?
Kerline: The second one, yes. I would give them the same food to see if the things they eat in the water and the things I give them now, which will make them healthy and which wouldn't make them healthy.
I: ...What do you think you would find?
Kerline: I see the one in the clean water might sooner not die than the one in the salt water, the dirty water. Because I see, I wouldn't have something in the dirty water and then see the one in the clean water die and the other survive! I wouldn't think that. I'd think the one in clean water has more vitamins in it than that, because the one in the dirty water eats any garbage it finds under the water. The other one doesn't eat just anything, he only eats what I give him.

In this example, Kerline explicitly builds a treatment into her design to evaluate the effects of garbage; a strong notion of contrast permeates her description (dirty water versus clean water; garbage or unhealthy food versus healthy food). Moreover, she is quite clear on what she expects to find and why. Specifically, she has thought through the deductive consequences of her hypothesis and shows that she understands her experimental design, the key phrase being: "The other one doesn't eat just anything, he only eats what I give him."

To summarize, in the post-interviews there is a distinct change in the students' scientific knowledge, reasoning and discourse. They clearly show that they have acquired knowledge about aquatic ecosystems. But even more than that, they show that they can use that knowledge productively for scientific inquiry. They no longer limit the range of their thinking to the

problem as given. They reason in terms of a larger system where that system is part of their knowledge base, as in the Harbor problem. Furthermore, they use hypotheses to organize and give direction to their reasoning. And they have begun to develop a sense of the function of experimentation in producing evidence to evaluate hypotheses.

That the students have begun to acquire a new discourse is perhaps most evident in the voices they use as they answer the interviewer's questions. In the pre-interviews, much of the students' discourse was enacted through the third person, with occasional uses of the first person when telling stories from personal experience. In the post-interviews, in contrast, the first person dominates, but it is an "I" that is distinctly different from the narrative "I" occasionally heard in the pre-interviews. In the post-interviews, as several of the preceding examples have shown, the "I" now functions authoritatively, that is, as the voice of an active problem solver.

Conclusion

As we have tried to suggest in this paper, the problem of trying to make sense in science (as much as in other disciplines) is in many respects exactly this problem of finding a voice, or controlling a new discourse, through which one can express one's own intentions, knowledge, experiences and values. As Cazden (1989) has suggested in a recent paper, following Bakhtin (1981), the struggle is not just to learn new ways of thinking, acting and using language but ways of appropriating particular discourses and the values of the contexts with which they are associated to one's own purposes. From the foregoing results, we hope it is clear that for these students, as for any students, learning to tell – in Medawar's phrase – good stories in science is not simply a matter of mastering a particular syntactic or explanatory form, as is typically emphasized in English-as-a-Second-Language instruction. Rather, learning to think and talk scientifically is a matter of understanding the approach to knowledge and reasoning, and the values and assumptions that science embodies, and of finding a way to accommodate one's purposes and values alongside those of the scientific and the school cultures. Authentic scientific activity, of the kind realized in the Cheche Konnen project (Rosebery et al., 1990; Warren, et al., 1989), is the means to that end.

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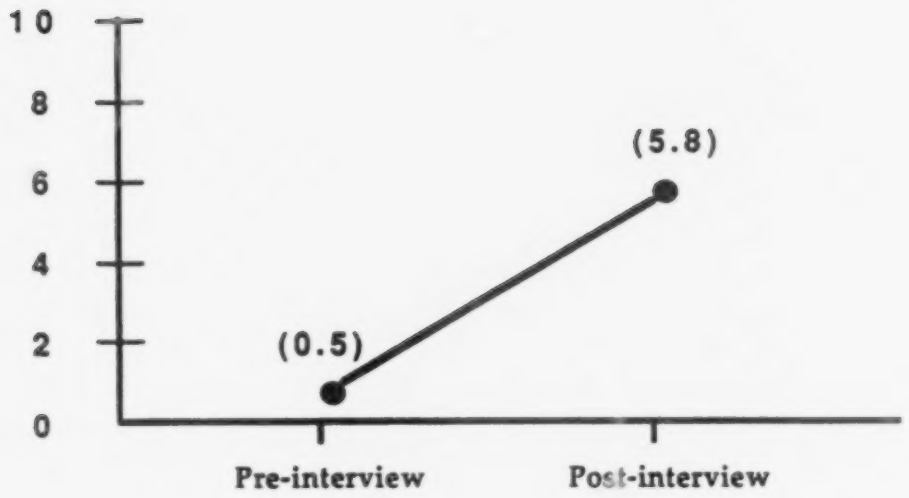

Figure 1. Mean number of concepts related to water quality mentioned spontaneously by students in pre- and post-interviews for the Boston Harbor problem (t=8.72, 15 d.f., p<0.000).

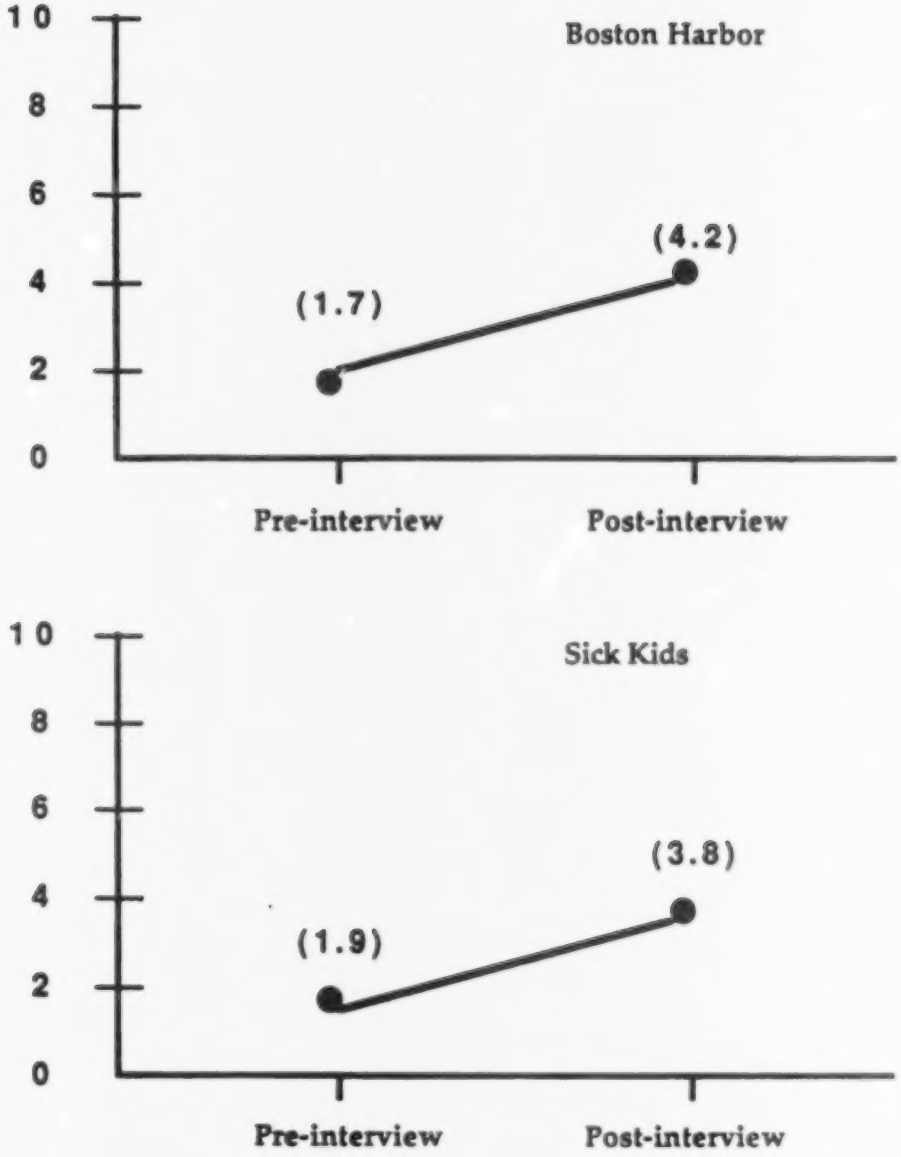

Figure 2. Mean number of hypotheses produced by students in the pre- and post-interviews for the Boston Harbor and Sick Kids problems, respectively ($t=8.26$, 15 d.f., $p<0.000$ and $t=7.3$, 15 d.f., $p<0.000$).

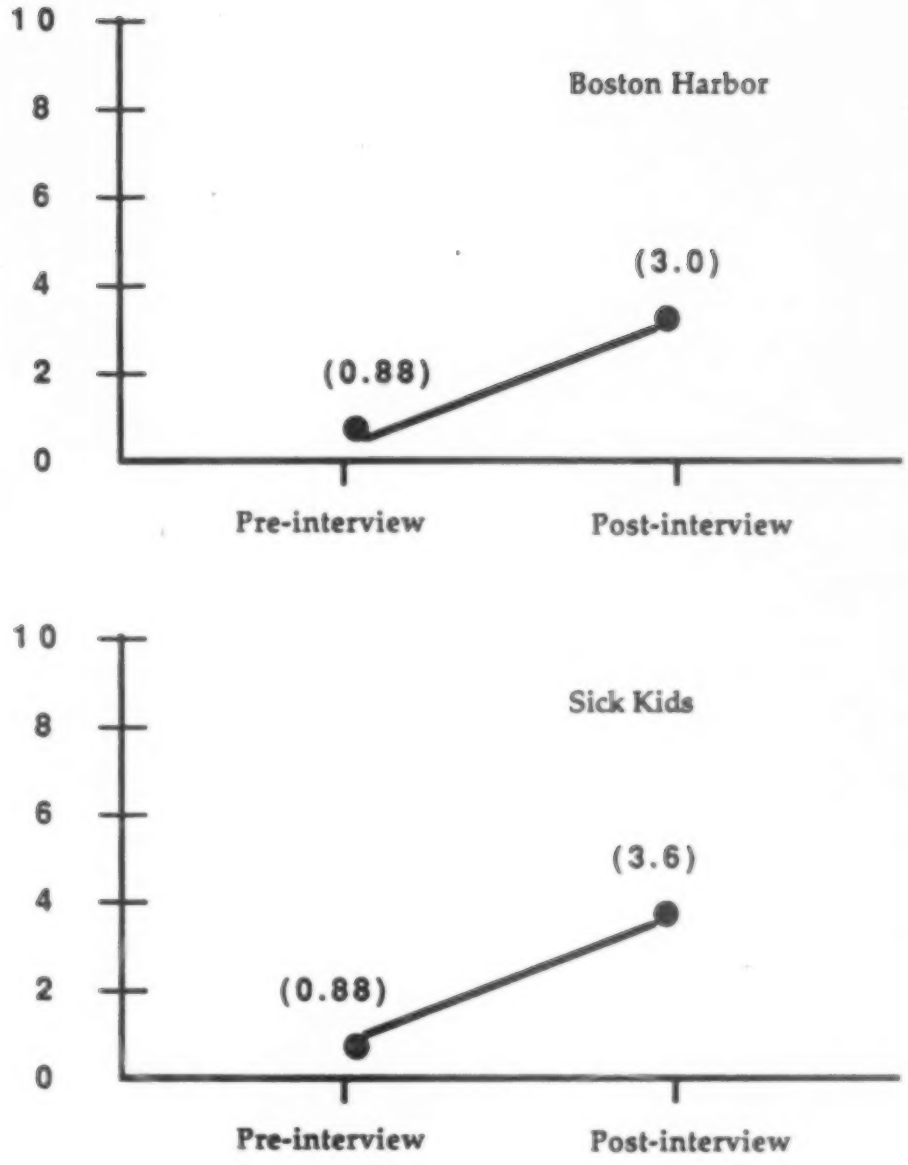

Figure 3. Mean number of experiments produced by students in the pre- and post-interviews for the Boston Harbor and Sick Kids problems, respectively ($t=7.1$, 15 d.f., $p<0.000$ and $t=11.0$, 15 d.f., $p<0.000$).

Table 1

Problem 1: Polluted Water

I'm going to tell you a true story; it's sort of a mystery. It's about the Boston Harbor. In the last few years, people have noticed that there is something wrong with the water in the Harbor but no one knows exactly what is wrong.

Fishermen have noticed that there are fewer fish in the Harbor. And they have seen a lot more algae. People who spend time near the Harbor have noticed that the water looks dirty; it is brown and foamy. It also has garbage in it. Tin cans, paper, and old food float in the water. Sometimes you can even see dead fish floating on the waves.

You are a famous scientist. The Mayor of Boston asks you to find out what is wrong with the water.

What is the first thing you do?
What do you think might be wrong with the water?
How will you find out if you are right?
Do you have any ideas about how you could make the water clean again?

Adapted from: Tye, Larry. (May 16, 1988). Boston Harbor: Cleaning the waters. The Boston Globe.

Problem 2: Sick School Children

I'm going to tell you another true story; it's a mystery, too. It's about some children in a school who get sick and, when it happened, no one knew what was making them sick.

It happened in a town around here, just outside Boston. All the children in an elementary school were watching a play put on by the sixth graders. Suddenly, a boy in the play fell off the stage and cut his chin. He said he felt sick and some teachers carried him to the nurse. Then a student watching the play got dizzy and fainted. Then some other students felt sick to their stomachs. Suddenly, lots of students were sick.

You are a famous scientist and you live next door to the school. When the children get sick, the principal runs over to your house and asks you to come and find out what is making the children sick. You agree and go to the school.

What is the first thing you do?
What do you think might be wrong with the water?
How will you find out if you are right?

Adapted from: Small, G.W. & Nicholi, A.M. (1982). Mass hysteria among schoolchildren: Early loss as a predisposing factor. Archives of General Psychiatry, 39, June. pp. 721-724.

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